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THE UNIVERSITY OF TENNESSEE
DEPARTMENT OF ELECTRICAL ENGINEERING

DEVELOPMENT OF A HIGH FREQUENCY STEERABLE ANTENNA

Navy Department
Bureau of Ships
Electronics Divisions

Interim Development
Report No.10

Contract No. NObsr-57448
Index No. NE-091035 ST7
10 July 1953

A PROJECT OF THE ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE COLLEGE OF ENGINEERING
Knoxville 16, Tennessee

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INTERIM DEVELOPMENT REPORT
FOR
DEVELOPMENT OF A HIGH FREQUENCY STEERABLE ANTENNA

This report covers the period
1 June 1953 to 30 June 1953

ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE
KNOXVILLE , TENNESSEE

Navy Department — Bureau of Ships
Electronics Divisions

Contract No. NObsr-57448 — Index No. NE-091035 ST7

10 July 1953

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ABSTRACT

This report covers work done on Contract No. NObsr-57448, Index No. NE-091035 ST7, at The University of Tennessee during the month of June 1953.

The following was accomplished:

1. Construction of the system for obtaining antenna patterns by means of an automatic recorder was completed. The antenna test facility is now being used to measure antenna impedances on Contract NObsr-57032.

2. The calculation of median expected field intensities was finished.

3. An assessment of the available information on angles-of-arrival was started.

4. The investigation of possible methods of steering horizontally the beam of a rhombic antenna was completed .

5. Work was resumed on the investigation of inclined radial wires to be used as tilted V-antennas.

6. The mathematical analysis of the radiation characteristics of a circular travelling-wave antenna was checked and some radiation patterns were calculated.

PART I

Purpose

This project invloves the development of a high frequency steerable antenna having the following characteristics:

1. It shall be operable throughout the frequency range of 4 to 32 megacycles per second.

2. It shall be capable of four, or more, simultaneous transmissions on different frequencies, and at different azimuth and elevation angles.

3. For each transmission, it shall be capable of being directed to any azimuth angle and to any elevation angle between the horizon and 30° above the horizon.

The communication system shall provide reliable 24-hour day-to-day communication with a 20-decibel signal-to-noise ratio. The ranges to be covered are from approximately 500 nautical miles to 4000 nautical miles.

The development consists of two phases:

Phase I. Theoretical and experimental studies.

Phase II. Development of design criteria.

General Factual Data

Personnel:

F. V. Schultz	Project Director	95	Man-hours
W. D. Leffell*	Assistant Engineer	54	Man-hours
W. J. Bergman	Junior Engineer	24	Man-hours
H. P. Neff	Junior Engineer	176	Man-hours
L. W. Ricketts*	Junior Engineer	119 1/2	Man-hours
G. R. Turner	Secy-Draftsman	33	Man-hours
G. D. Goan*	Technician	2	Man-hours
L. Phillips*	Technician	160	Man-hours
W. H. Williams*	Technician	66	Man-hours
H. Knox	Student Computer	69	Man-hours
D. Marcum	Student Computer	14	Man-hours
N. Boyd	Typist	4	Man-hours
A. Rich	Multilith-Operator	3	Man-hours
E. G. Shelton *	Civil Engineering Consultant	6	Man-hours

* Preparation of antenna test facility.

References

Bruce, E. and Beck, A. C., "Experiments with Directivity Steering for Fading Reduction," Bell System Technical Journal, Vol. 14, p. 195, April 1935.

Bruce, E., Beck, A. C., and Lowry, L. R., "Horizontal Rhombic Antennas," Proceedings of the Institute of Radio Engineers, Vol. 23, p. 24, January 1935.

Foster, Donald, "Radiation fromRhombic Antennas," Proceedings of the Institute of Radio Engineers, Vol. 25, p. 1327, October 1937.

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Harrison, C. W., "Radiation from Vee Antennas," Proceedings of the Institute of Radio Engineers, Vol. 31, p. 362, July 1943.

Harrison, C. W., "The Radiation Field of Long Wires, with Application to Vee Antennas," Journal of Applied Physics, Vol. 14, p. 537, October 1943.

Harrison, C. W., "The Inclined Rhombic Antenna," Proceedings of the Institute of Radio Engineers, Vol. 30, p. 241, May 1942.

"Ionospheric Radio Propagation," U. S. Department of Commerce, National Bureau of Standards Circular No. 462, June 1948, Washington D. C.

Knudsen, H. L., "The Field Radiated by a Ring Quasi-Array of an Infinite Number of Tangential or Radial Dipoles," Proceedings of the Institute of Radio Engineers, Vol. 41, p. 781, June 1953.

Kraus, J. D., Antennas, McGraw-Hill Book Co., Ind., New York, 1950, Chapter 2.

Sherman, J. B., "Circular Loop Antennas at Ultra-High Frequencies," Proceedings of the Institute of Radio Engineers, Vol. 32, p. 534, September 1944.

Williams, H. P., Antenna Theory and Design, Pitman and Sons, Ltd., London, 1950.

Detail Factual Data

1. Construction has been completed on the system for controlling the motion of the antenna mount from within the building at the test facility, and also on the selsyn system for driving the recorder in synchronism with the antenna mount. This antenna mount is to be used for holding the model antennas under test, especially during the obtaining of the antenna patterns.

   A 20-foot boom has been built for elevating the test pick-up antenna above the plane of the model antenna under test in order to be able to obtain complete radiation patterns.

2. Median expected field intensities for the month of June 1947 were completed and the results are listed in Tables 1 to 3 of this report. This completes the calculation of expected field intensities when using an isotropic source radiating one kilowatt effective radiated power in all directions. An analysis of the significance of these results must be deferred until all available data on angles-of-arrival have been examined and necessary antenna beamwidths determined.

3. More data on angles-of-arrival have been received and an assessment of the information has been started. Efforts are being continued to uncover recent data which have not yet been published. This is especially important here because of the meagerness of the available data and because of fairly recent improvements in the measurement techniques.

4. One of the methods which has been investigated for steering the beam of a rhombic antenna in azimuth is that of making adjacent legs of the rhombic of unequal size. It is well known that the direction of the main lobe of radiation of a long wire carrying traveling waves approaches the direction of the wire as the length of the wire (in wavelengths) increases. As the angle the main lobe makes with the wire axis gets smaller (with increasing length) the main lobe also becomes smaller in width. (See Figure 1).

   It was believed that this angular variation of the main lobes of component wires would permit steering a modified rhombic. Geometrically, the procedure is as follows: In the ordinary case of a rhombic antenna the radiation lobes from adjacent (see Figure 2) legs are very nearly lined up with each other, combining to form a single lobe similar to that of the individual wires.

Detail Factual Data - Continued

The shaded lobes of Figure 2 combine in the desired direction (the main axis in this case) to form the main beam of the complete antenna. If it is desired to make the main beam line up at some arbitrary angle to the main antenna axis, the problem is similar to the following example.

For instance, assume angle A in Figure 2 is 60^{o}, making $1/2\ A = 30^{o}$. Furthermore assume that it is desired to steer 10^{o} to the left of the main axis. If legs (1) and (3) are made $1.5\ \lambda$ long the main lobe from these legs occurs at an angle of 40^{o} (see Figure 1) from the wire axis, giving the desired 10^{o} steering. Legs (2) and (4) must be made $6.1\ \lambda$ long, giving maximum radiation at 20^{o} to their axes (see Figure 1) and the required 10^{o} steering. This is shown in Figure 3.

Actually, these leg lengths do not give maximum radiation at -10^{o}. The leg lengths for maximum radiation must be investigated mathematically.

Assuming free space and horizontal polarization, an expression can be derived for the radiation characteristics of this type antenna. Using the methods of Bruce, Beck, and Lowry this expression is:

$$I_R = K' \left[\frac{\cos(\phi + \beta)}{1-\sin(\phi + \beta)} + \frac{\cos(\phi - \beta)}{1-\sin(\phi - \beta)} \right]$$

$$\times \sin \frac{\pi \ell_2}{\lambda} \left[1 - \sin(\phi - \beta) \right]$$

$$\times \sin \frac{\pi \ell_1}{\lambda} \left[1 - \sin(\phi + \beta) \right] ,$$

where I_R is the receiver current, for a wave in the plane of the antenna (elevation angle, $\Delta = 0^{o}$). The angles and dimensions are shown in Figure 3. Differentiating this equation with respect to ℓ_1, and setting it equal to zero gives the value of ℓ_1 for maximum receiver current. The same procedure gives a value for ℓ_2 which maximizes the original equation. These values of ℓ_1 and ℓ_2 are:

$$\ell_1 = \frac{\lambda}{2\left[1-\sin(\phi + \beta)\right]}$$

Detail Factual Data - Continued

$$\ell_2 = \frac{\lambda}{2\left[1-\sin(\phi - \beta)\right]}$$

Using these values in the preceding equations ($\phi = 60^o$), ($\beta = -10^o$) :

$$\ell_1 = 2.14\lambda$$

$$\ell_2 = 8.30\lambda$$

As shown in Figure 4, the desired result (maximum receiver current) is obtained, but the sidelobe level is high. Figure 5 is a compromise design of reduced size but better sidelobe level, retaining the 10^o steering. The sidelobe level is reduced by obtaining better sidelobe cancellation with the slightly different leg lengths.

Unfortunately there are obvious limitations to this method of steering. No long wire can radiate along its own axis, and we may further say that radiation must not occur from a long wire at an angle less than about $\pm 15^o$ from the wire, since the beam width would be too small and the leg length too large for practical considerations, (see Figure 1). Of course the adjacent leg may radiate in this direction (because of the angular displacement of the two adjacent wires), but the effectiveness of this antenna depends on the combination of adjacent lobes, and alignment or combination would be impossible at these positions. This limits the steering to $\pm 15^o$ or $\pm 20^o$ between the wires. Steering outside of one of the adjacent wires can be accomplished, but with increased sidelobe level and frequency sensitivity. This method probably cannot be used to meet the present requirements, because of its limitations.

5. Work was resumed on the investigation of inclined radial wires to be used as tilted V-antennas. Formulas are available which predict the performance of tilted V-antennas over an infinitely-conductive plane and also over a plane having finite constants. The latter is, of course, the case of importance but the formulas pertaining thereto are extremely complicated. Efforts are being made to get these formulas into a form more suitable for calculation purposes.

   Since it is desirable to make model tests of this antenna over a plane of finite constants, efforts are underway to obtain sheets of material having certain conductivities to be used as the ground screen in the model tests.

Detail Factual Data - Continued

It has been learned that both the Signal Corps and the Air Force are considering the use of such antennas and that the antennas are often called "Maypoles". Some information has been obtained concerning the work being done by the other services on this antenna and more information has been requested.

6. The mathematical analysis of the radiation characteristics of a circular travelling-wave antenna has been checked and some radiation patterns have been calculated. These patterns are not suitable, as they stand, for use on the present project so an investigation is underway to find some method of improving the radiation characteristics of the antenna.

DEPARTMENT OF ELECTRICAL ENGINEERING
ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE

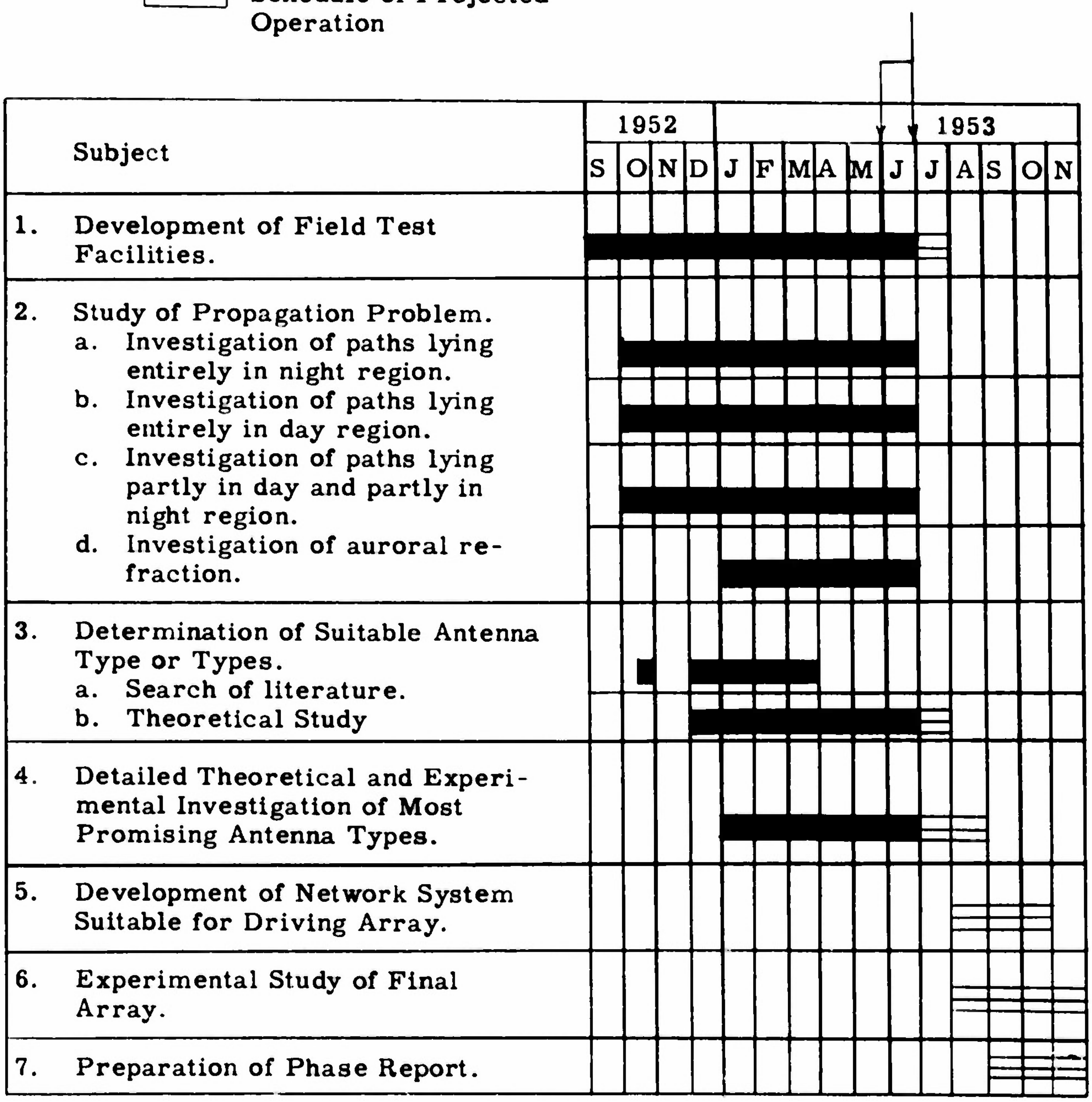
PROJECT PERFORMANCE AND SCHEDULE

Index No. NE-091035 ST7

Contract No. NObsr-57448 | Date: 10 July 1953

Legend: ■ Work Performed | Period Covered: 1/6/53 to 30/6/53

▭ Schedule of Projected Operation



Conclusions

1. The work on the propagation problem has not progressed far enough to allow the drawing of any conclusions.

2. The attempt to steer horizontally the beam of a rhombic antenna by using legs of different lengths was somewhat successful in that some steering can be accomplished. It appears, however, that other methods of obtaining horizontal steering offer more promise.

3. Not enough results are available as yet on the "Maypole" antenna and the circular traveling-wave antenna to allow the drawing of any conclusions.

Program for Next Interval

1. The analysis of the available data on angles-of-arrival will be continued.

2. The study of the "Maypole" antenna will continue and efforts will be made to determine the radiation patterns, especially the vertical pattern. Attempts will be made, also, to obtain information from other organizations on this type of antenna.

3. Work will go forward on the circular travelling-wave antenna to try to obtain radiation characteristics which will meet the requirements of this project.

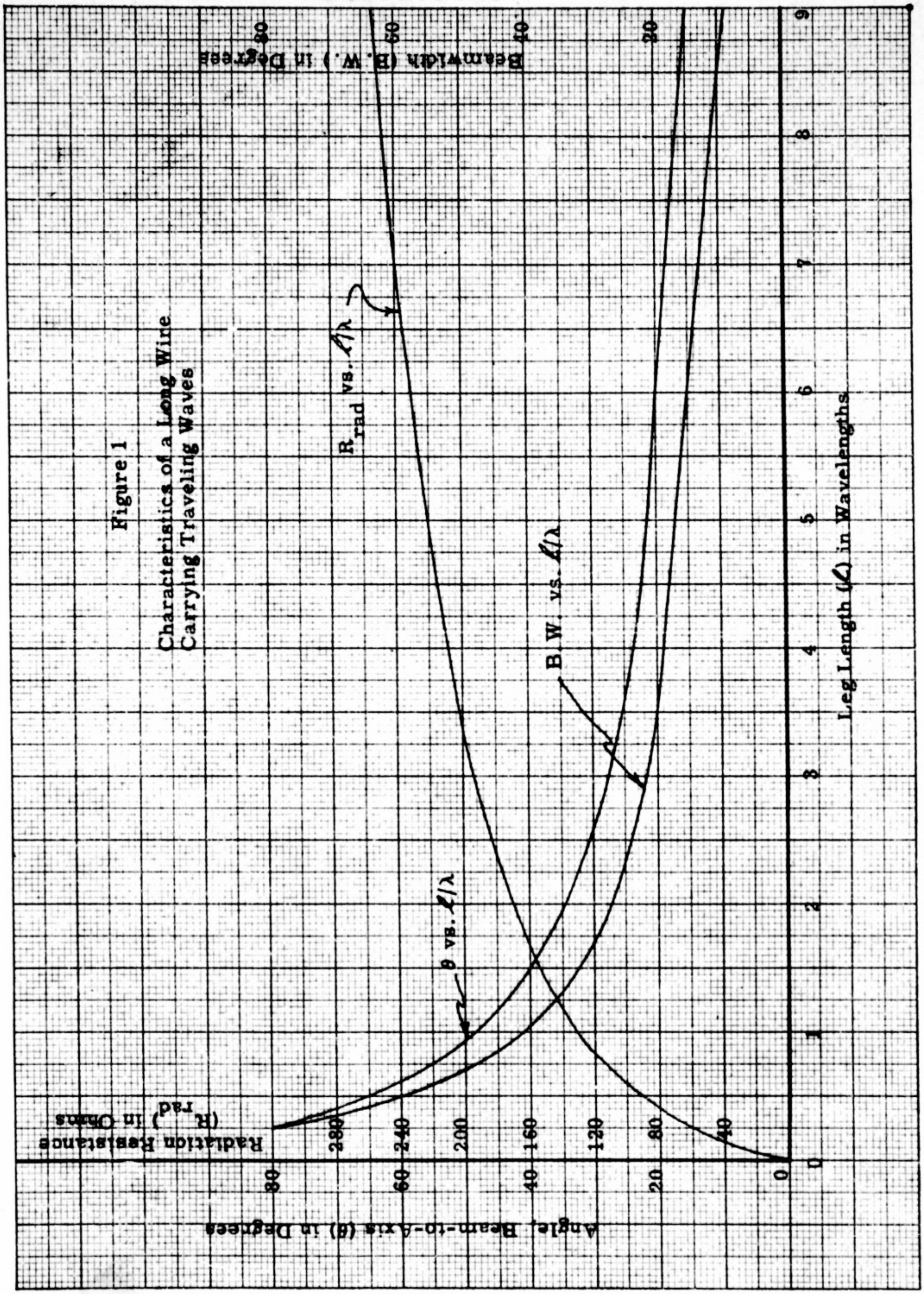


Figure 1

Characteristics of a Long Wire Carrying Traveling Waves

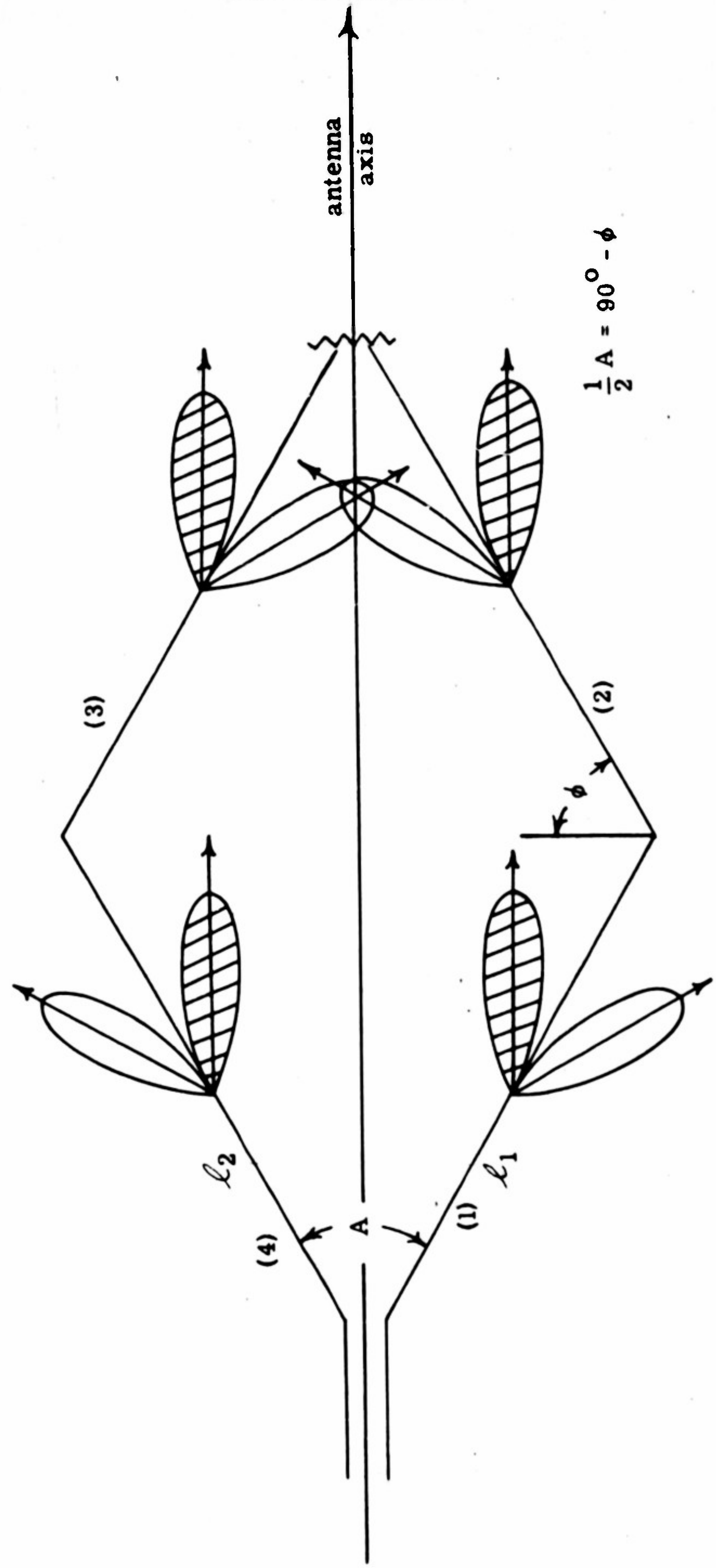
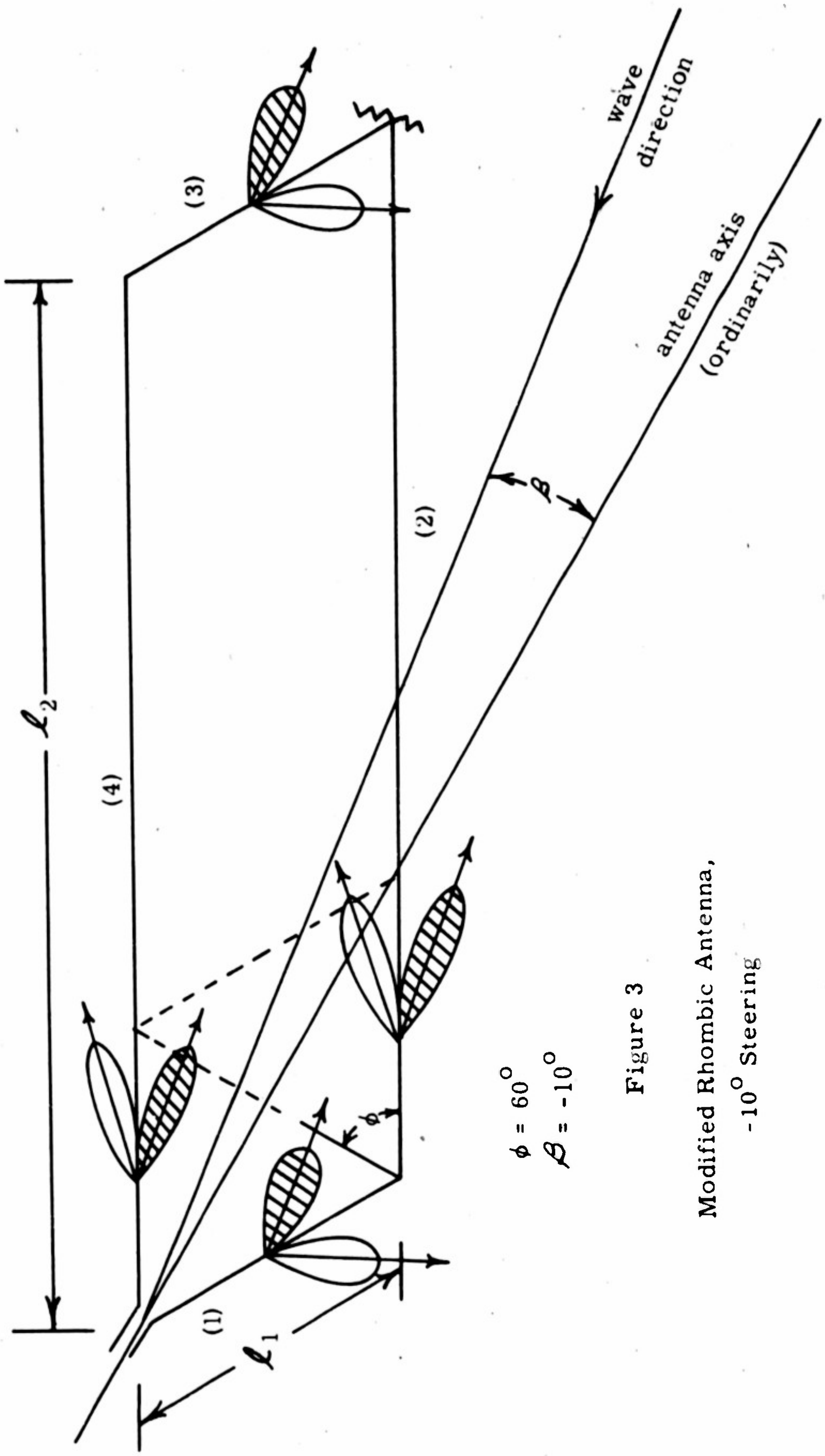


Figure 2
Rhombic Antenna Alignment



$\phi = 60^{\circ}$
$\beta = -10^{\circ}$

Figure 3

Modified Rhombic Antenna, -10° Steering

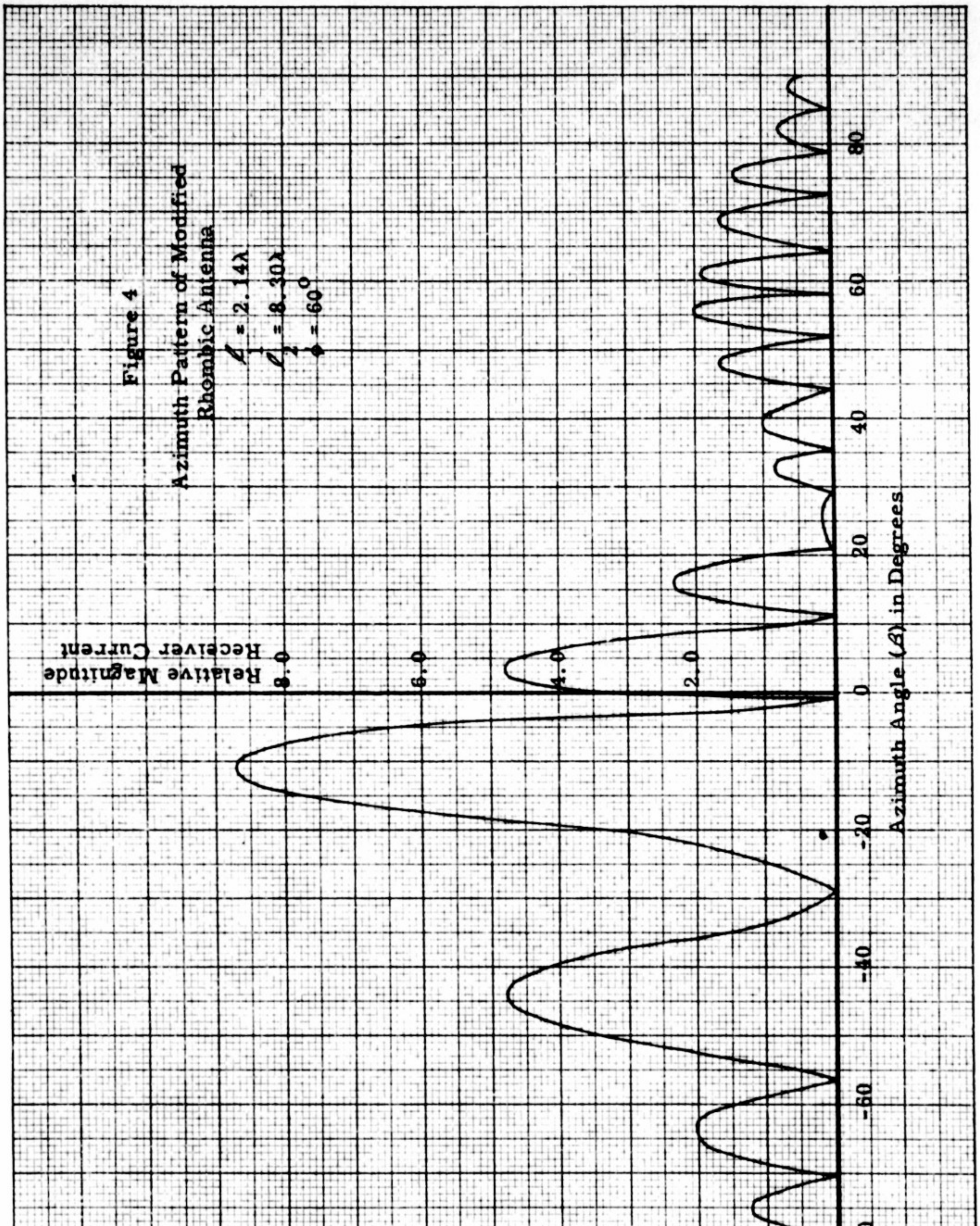


Figure 4

Azimuth Pattern of Modified Rhombic Antenna

$\ell_1 = 2.14\lambda$

$\ell_2 = 8.30\lambda$

$\phi = 60^{\circ}$

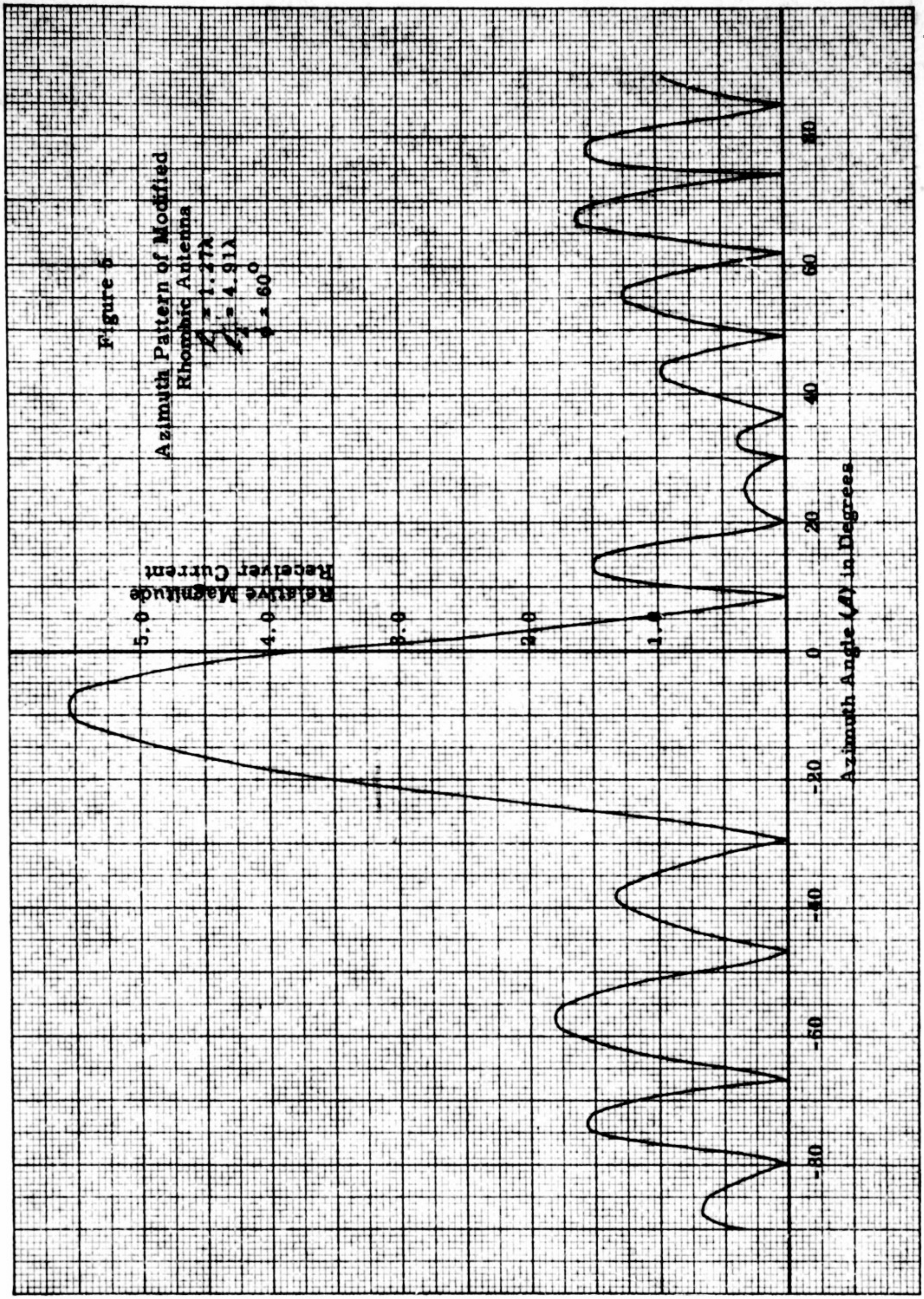


Figure 5
Azimuth Pattern of Modified
Rhombic Antenna
ℓ1 = 1.27λ
ℓ2 = 4.91λ
φ = 60°
Relative Magnitude
Receiver Current
5.0
4.0
3.0
2.0
1.0
-80
-60
-40
-20
0
20
40
60
80
Azimuth Angle (A) in Degrees

TABLE I

Field Strengths Calculated for a Transmitter Located at Port Lyautey, French Morocco

Calculations made for: June 1947; Sunspot number = R = 112; 1 kilowatt effective radiated power; 0000 hours and 1200 hours.

North from Port Lyautey

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 µv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 µv/m
800	432	1-Hop-F2	6.6	44.5	5.8	44.5
1200	648	1-Hop-F2	8.0	42.0	7.0	42.0
3200	1728	1-Hop-F2	16.4	34.5	13.6	34.5

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 µv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 µv/m
800	432	1-Hop-F2	9.6	33.0	8.2	27.0
1200	648	1-Hop-F2	12.2	30.5	10.0	25.0
3200	1728	1-Hop-F2	20.5	23.0	18.2	22.0

TABLE 1
(continued)

South from Port Lyautey

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.0	44.5	6.6	44.5
1200	648	1-Hop-F2	10.0	42.0	8.4	42.0
3200	1728	1-Hop-F2	22.2	34.5	20.6	34.5
8000	4320	1-Hop-F2	15.7	23.0	12.0	23.0

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	10.3	34.5	9.8	33.0
1200	648	1-Hop-F2	13.3	32.5	12.6	31.0
3200	1728	1-Hop-F2	36.0	31.0	30.6	30.5
8000	4320	1-Hop-F2	33.0	15.5	29.0	+12.0

TABLE 1
(continued)

East from Port Lyautey

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 $\mu v/m$	Operating Frequency (Mc.)	Median Field Intensity (db above 1 $\mu v/m$
800	432	1-Hop-F2	7.0	44.5	6.0	44.5
1200	648	1-Hop-F2	8.4	42.0	7.4	42.0
3200	1728	1-Hop-F2	14.4	34.5	12.6	34.5
8000	4320	1-Hop-F2	14.9	21.5	13.4	+21.0

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 $\mu v/m$	Operating Frequency (Mc.)	Median Field Intensity (db above 1 $\mu v/m$
800	432	1-Hop-F2	9.6	32.5	8.5	28.0
1200	648	1-Hop-F2	11.7	29.0	10.4	28.5
3200	1728	1-Hop-F2	20.6	23.0	18.0	21.0
8000	4320	1-Hop-F2	21.7	10.5	18.8	+3.5

TABLE 1
(continued)

West from Port Lyautey

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	7.6	44.5	5.8	44.5
1200	648	1-Hop-F2	9.5	42.0	7.0	42.0
3200	1728	1-Hop-F2	15.8	34.5	12.2	34.5
8000	4320	1-Hop-F2	20.8	22.0	13.4	+21.0

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	11.2	30.0	8.2	27.0
1200	648	1-Hop-F2	13.6	27.0	10.0	25.0
3200	1728	1-Hop-F2	20.0	22.0	17.2	20.0
8000	4320	1-Hop-F2	21.0	+2.0	17.8	1.5

TABLE 2

Field Strengths Calculated for a Transmitter Located at Seattle, Washington

Calculations made for: June 1947; Sunspot number = R = 112; 1 kilowatt effective radiated power; 0000 hours and 1200 hours.

North from Seattle

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	7.6	44.5	6.4	44.5
1200	648	1-Hop-F2	10.0	42.0	8.6	42.0
3200	1728	1-Hop-F2	15.8	34.5	15.4	33.5

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.5	31.0	6.4	22.0
1200	648	1-Hop-F2	10.5	28.0	8.6	22.0
3200	1728	1-Hop-F2	15.8	18.0	15.4	18.0

TABLE 2
(continued)

South from Seattle

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	6.4	44.5	5.6	44.5
1200	648	1-Hop-F2	7.8	42.0	6.8	42.0
3200	1728	1-Hop-F2	16.0	34.5	13.4	34.5
8000	4320	1-Hop-F2	17.0	23.0	15.6	23.0

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.6	30.0	7.6	26.5
1200	648	1-Hop-F2	11.0	28.5	9.6	24.0
3200	1728	1-Hop-F2	20.3	22.0	18.0	19.0
8000	4320	1-Hop-F2	22.0	7.0	20.6	0.0

TABLE 2
(continued)

East from Seattle

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	6.7	44.5	6.6	44.5
1200	648	1-Hop-F2	8.0	42.0	6.8	42.0
3200	1728	1-Hop-F2	12.7	34.5	12.6	34.5
8000	4320	1-Hop-F2	14.5	14.0	13.8	13.0

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	7.7	27.5	6.6	23.0
1200	648	1-Hop-F2	9.6	26.0	9.2	24.0
3200	1728	1-Hop-F2	16.7	19.5	16.0	19.0
8000	4320	1-Hop-F2	17.0	7.0	17.0	7.0

TABLE 2
(continued)

West from Seattle

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	7.7	44.5	6.6	44.5
1200	648	1-Hop-F2	9.8	42.0	7.6	42.0
3200	1728	1-Hop-F2	19.1	34.5	17.2	34.5
8000	4320	1-Hop-F2	19.5	16.0	17.8	16.0

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.5	30.0	6.6	23.0
1200	648	1-Hop-F2	10.4	27.0	7.6	17.0
3200	1728	1-Hop-F2	19.1	23.0	17.2	22.0
8000	4320	1-Hop-F2	19.5	10.5	17.8	+7.0

TABLE 3

Field Strengths Calculated for a Transmitter Located at Adak, Alaska.

Calculations made for: June 1947; Sunspot number = R = 112; 1 kilowatt effective radiated power; 0000 hours and 1200 hours.

North from Adak

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.3	44.5	7.6	44.5
1200	648	1-Hop-F2	10.2	42.0	9.4	42.0
3200	1728	1-Hop-F2	18.3	33.0	16.6	32.2

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	9.3	30.5	7.6	28.0
1200	648	1-Hop-F2	11.0	28.0	9.4	26.0
3200	1728	1-Hop-F2	17.5	22.0	16.6	21.0

TABLE 3
(continued)

South from Adak

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	7.0	44.5	6.0	44.5
1200	648	1-Hop-F2	7.8	42.0	7.2	42.0
3200	1728	1-Hop-F2	22.8	34.5	13.6	34.5
8000	4320	1-Hop-F2	17.4	23.0	14.8	23.0

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.6	29.0	8.0	29.0
1200	648	1-Hop-F2	10.0	27.0	9.6	25.0
3200	1728	1-Hop-F2	28.5	24.5	19.2	21.0
8000	4320	1-Hop-F2	23.7	9.0	21.2	0.0

TABLE 3
(continued)

East from Adak

0000 Hours

Distance Km.	Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	8.2	44.5	7.6	44.5
1200	648	1-Hop-F2	10.2	42.0	9.2	42.0
3200	1728	1-Hop-F2	15.9	34.5	15.0	30.0
8000	4320	1-Hop-F2	14.4	7.0	12.6	+2.0

1200 Hours

Distance Km.	Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 μv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 μv/m
800	432	1-Hop-F2	9.5	32.0	7.6	28.0
1200	648	1-Hop-F2	10.6	29.0	9.2	25.0
3200	1728	1-Hop-F2	16.0	19.0	15.0	18.0
8000	4320	1-Hop-F2	16.2	6.0	12.6	-3.0

TABLE 3
(continued)

West from Adak

0000 Hours

Distance Km.	Distance Nautical Miles	Trans Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 µv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 µv/m
800	432	1-Hop-F2	9.4	44.5	7.8	44.5
1200	648	1-Hop-F2	10.3	42.0	9.2	42.0
3200	1728	1-Hop-F2	18.7	34.0	17.0	33.0
8000	4320	1-Hop-F2	17.8	7.3	12.8	+12.0

1200 Hours

Distance Km.	Distance Nautical Miles	Trans. Mode	Opt. Working Frequency (Mc.)	Median Field Intensity (db above 1 µv/m	Operating Frequency (Mc.)	Median Field Intensity (db above 1 µv/m
800	432	1-Hop-F2	9.3	34.5	7.8	29.0
1200	648	1-Hop-F2	11.0	29.0	9.2	25.0
3200	1728	1-Hop-F2	18.7	25.5	17.0	21.0
8000	4320	1-Hop-F2	18.3	9.5	17.8	+9.0